Deployment options for OSGi applications in the cloud/edge

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Speaker

Dirk Fauth
Research Engineer
Eclipse Committer

ETAS GmbH
Borsigstraße 24
70469 Stuttgart

dirk.fauth@etas.com
www.etas.com

blog.vogella.com/author/fipro/
Twitter: fipro78

Deployment options for OSGi applications in the cloud/edge

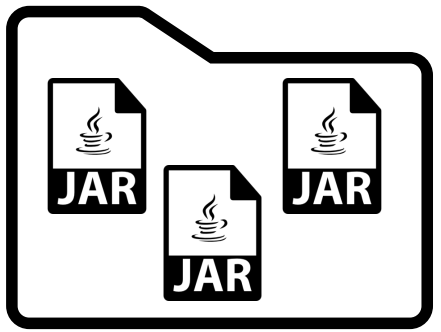
Overview

1. **Deployment Variants**
2. **Container**
3. **Benchmark**
4. **Conclusion**

Deployment Variants

Deployment Variants

General



+ Java JRE

Multiple JARs in a folder

+ Java JRE

Executable JAR

Java™

Custom JRE (jlink)

GraalVM™

Native Executable

Deployment Variants

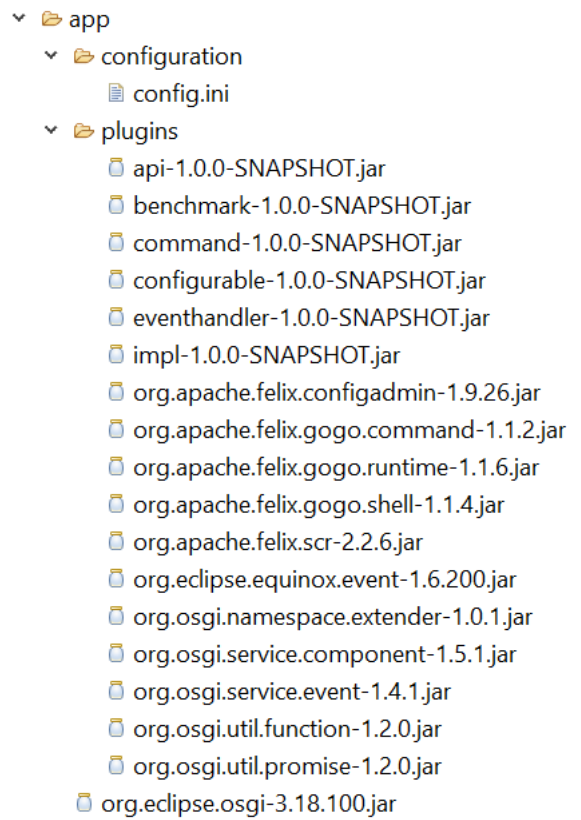
Multiple JARs in a folder

- Multiple JAR files (OSGi bundles) inside a folder
- Additional configuration file
- Launcher

  `org.eclipse.osgi`
  `:org.eclipse.core.runtime.adaptor.EclipseStarter`

```
java -jar org.eclipse.osgi-3.18.100.jar
```

- Build
  - `maven-dependency-plugin`
  - `maven-resources-plugin`



https://www.eclipse.org/equinox/documents/quickstart-framework.php

Deployment Variants

Executable JAR

– Executable JAR that includes each required bundle as embedded JAR file
– Configuration also included in the executable JAR
– Launcher
  `aQute.launcher.pre.EmbeddedLauncher`

```
java -jar equinox-app.jar
```

- Build
  - `bnd-maven-plugin`
  - `bnd-export-maven-plugin`

https://bnd.bndtools.org/
https://bndtools.org/
https://github.com/bndtools/bnd/tree/master/maven-plugins

Deployment Variants

Custom JRE via jlink

– Create a custom JRE with `jlink` command of the JDK
  – *assemble and optimize a set of **modules** and their dependencies into a custom runtime image*

https://docs.oracle.com/en/java/javase/17/docs/specs/man/jlink.html

– Folder layout like JRE
– Launcher: `java` command

```
/app/jre $ ls -l
total 20
drwxr-xr-x 2 appuser appuser 4096 Oct 14 08:37 bin
drwxr-xr-x 4 appuser appuser 4096 Oct 14 08:37 conf
drwxr-xr-x 9 appuser appuser 4096 Oct 14 08:37 legal
drwxr-xr-x 4 appuser appuser 4096 Oct 14 08:37 lib
-rw-r--r-- 1 appuser appuser  140 Oct 14 08:37 release
/app/jre $
```

```
java [options] -m <module>[/<mainclass>]
```

– Issue with OSGi and jlink
  Most available OSGi bundles do not contain a `module-info.class`
  → **`automatic module cannot be used with jlink`**

JPMS

Deployment Variants

Native Executable with GraalVM

– *Native Image is a technology to compile Java code ahead-of-time to a binary – a native executable. A native executable includes only the code required at run time, that is the application classes, standard-library classes, the language runtime, and statically-linked native code from the JDK.*

– Can be created using the GraalVM `native-image` tool
  – From a **Class**, a **JAR (classpath)** or a **Module (modulepath)**

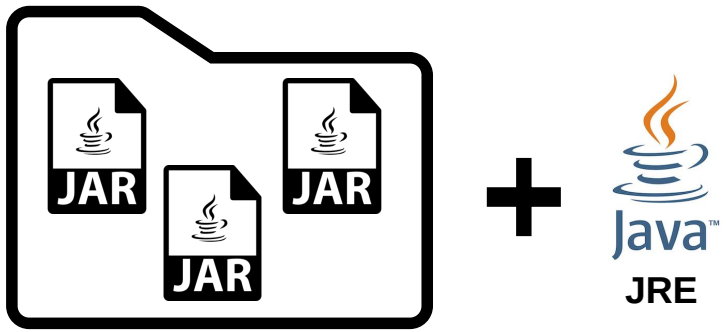
– "Closed world assumption"
  → all the bytecode in your application that can be called at run time must be known at build time

– Issue with OSGi and `native-image`
  Dynamic classloading per bundle managed by OSGi Framework (Module Layer)
  `java.lang.NullPointerException: A null service reference is not allowed.`

https://www.graalvm.org/reference-manual/native-image/

Deployment Variants

OSGi



Multiple JARs in a folder

Executable JAR

Custom JRE (jlink)

Native Executable

Deployment Variants

Custom JRE via jlink - OSGi

– Add `module-info.class`

  – ModiTect
    https://github.com/moditect/moditect
    → Intrusive change that adds an artifact to an existing published JAR
      OSS license compatibility?
      Checksum?
    → Requires knowledge on internals for generation
      Maintenance?

  – **Bndtools JPMS Support**
    https://bnd.bndtools.org/chapters/330-jpms.html

Deployment Variants

Bndtools JPMS Support

Enable creation of `module-info.class` for each bundle, e.g. via `bnd-maven-plugin`

```
<plugin>
  <groupId>biz.aQute.bnd</groupId>
  <artifactId>bnd-maven-plugin</artifactId>
  <configuration>
    <bnd>
      <![CDATA[
Bundle-SymbolicName: ${project.groupId}.${project.artifactId}
-sources: true
-contract: *
-jpms-module-info:org.fipro.service.command;modules='org.apache.felix.configadmin'
-jpms-module-info-options: org.osgi.service.cm;ignore="true"
]]>
    </bnd>
  </configuration>
</plugin>
```

Deployment Variants

Bndtools JPMS Support

Enable creation of `module-info.class` for **executable jar** via `.bndrun` file

```
-jpms-module-info: \
    ${project.groupId}.equinox.${project.artifactId};\
        version=${project.version};\
        ee=JavaSE-${java.specification.version}
-jpms-module-info-options: jdk.unsupported;static=false
```

This makes the executable jar itself a module!

Deployment Variants

Custom JRE via jlink with Bndtools JPMS support

Build

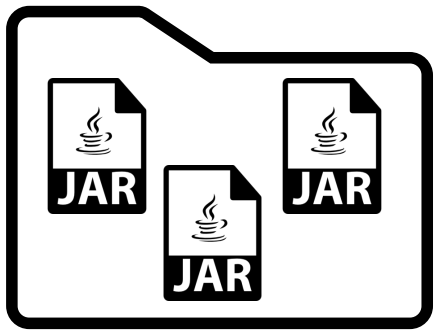
```
$JAVA_HOME/bin/jlink \
    --add-modules org.fipro.service.equinox.app \
    --module-path equinox-app.jar \
    --no-header-files \
    --no-man-pages \
    --output /app/jre
```

Launch

```
/app/jre/bin/java \
  -m org.fipro.service.equinox.app/aQute.launcher.pre.EmbeddedLauncher
```

Deployment Variants

OSGi



+ Java JRE

Multiple JARs in a folder

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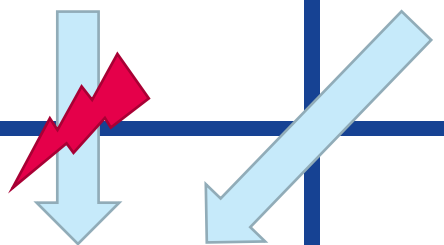
Executable JAR



Custom JRE (jlink)

Native Executable

Deployment Variants

OSGi Connect

– *OSGi Connect allows for bundles to exist and be installed into the OSGi Framework from the flat class path, the module path (Java Platform Module System), a jlink image, or a native image.*

→ Allows to start an OSGi application without the full OSGi Module Layer

OSGi Core R8 – Connect Specification
https://docs.osgi.org/specification/osgi.core/8.0.0/framework.connect.html

Apache Felix Atomos
https://github.com/apache/felix-atomos

Ubiquitous OSGi - Android, Graal Substrate, Java Modules, Flat Class Path
https://www.youtube.com/watch?v=KxmtzjHBumU

OSGi R8, Felix 7, Atomos and the future of OSGi@Eclipse
https://www.youtube.com/watch?v=oitFMbztf5s

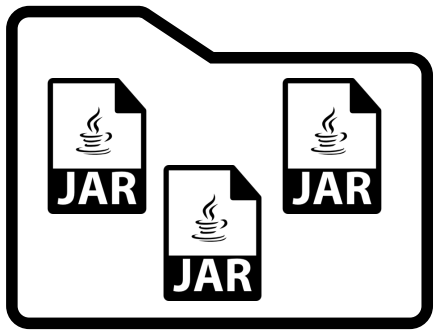
Deployment Variants

GraalVM Native Image with OSGi Connect

- **Preparation**
  1. Add/use Atomos to be able to start the OSGi application from the flat classpath
  2. Generate reachability metadata via tracing agent (reflection, resources, …)
  3. Update generated metadata
- **Build**
  - Via GraalVM build plugins (Maven/Gradle)
  - Docker multi-stage build using GraalVM container images
- **Notes/Remarks**
  - `native-image` build only worked with **flat classpath** and **listing all jars explicitly**
  - Build result is platform-dependent
  - `atomos_lib` folder or index file needed for Atomos to discover bundles and load bundle entries
  - Still not everything is working as expected (e.g. `scr:list` produces an empty output)

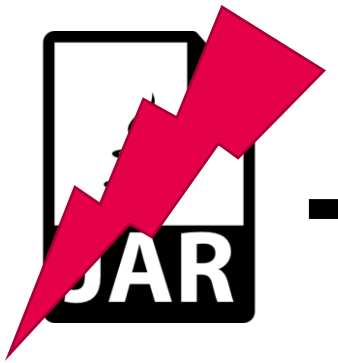
Deployment Variants

OSGi Connect / Apache Felix Atomos



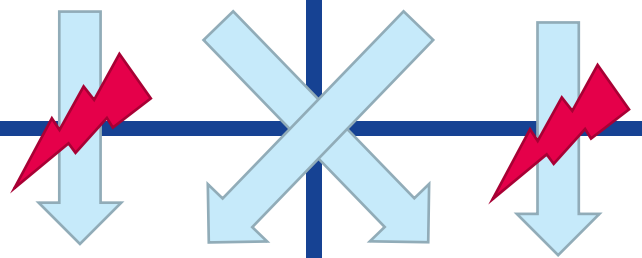
+ Java JRE

Multiple JARs in a folder



+ Java JRE

Executable JAR



Java™

Custom JRE (jlink)

GraalVM™

Native Executable

Deployment Variants

Deployment (plain OSGi)
Multiple JARs in folder
Executable JAR
Custom JRE (jlink)
~~GraalVM Native Image~~

Deployment (OSGi Connect)
Multiple JARs in folder
~~Executable JAR~~
Custom JRE (jlink)
GraalVM Native Image

Container

Container

“Size matters” – Find the right base image

Alpine vs. Debian vs. Ubuntu

Image	Size
alpine:3	5.54 MB
debian:bullseye-slim	80.50 MB
ubuntu:jammy	77.84 MB

Eclipse Temurin vs. IBM Semeru

JDK vs. JRE

Image	Size
eclipse-temurin:17-jdk-jammy	~ 455 MB
eclipse-temurin:17-jdk-alpine	~ 356 MB
eclipse-temurin:17-jre-jammy	~ 266 MB
eclipse-temurin:17-jre-alpine	**~ 168 MB**
ibm-semeru-runtimes:open-17-jdk-jammy	~ 477 MB
ibm-semeru-runtimes:open-17-jre-jammy	~ 272 MB

Container

Interlude: Distroless

– *"Distroless" images contain only your application and its runtime dependencies. They do not contain package managers, shells or any other programs you would expect to find in a standard Linux distribution.*

Image		Size
gcr.io/distroless/static-debian11	minimal Linux for "mostly-statically compiled" languages that do not require libc	2.36 MB
gcr.io/distroless/base-debian11	minimal Linux, glibc-based system	20.32 MB
gcr.io/distroless/java17-debian11	base image plus OpenJDK 17 and its dependencies	230.88 MB

– Distroless Java image is based on Debian and glibc, therefore bigger than an Alpine Temurin image
– Can be interesting in production for security reasons, but not for size

https://github.com/GoogleContainerTools/distroless

Container

Java Best Practices

- Install only what you need
  - Use JRE instead of JDK
  - Use multi-stage builds (e.g. to create JRE or Native Image)

- Don’t run Java apps as root

- Properly shutdown and handle events to terminate a Java application

- Take care of “container-awareness”

https://snyk.io/blog/best-practices-to-build-java-containers-with-docker/
https://developers.redhat.com/articles/2022/04/19/java-17-whats-new-openjdks-container-awareness#
https://blog.openj9.org/2021/06/15/innovations-for-java-running-in-containers/

Container

Building Docker Images

– Use dedicated Docker files instead of generation tools

– Integrate image creation as part of the build via **`fabric8io/docker-maven-plugin`**
Maven/Gradle first

https://github.com/fabric8io/docker-maven-plugin
http://dmp.fabric8.io/

```
<plugin>
  <groupId>io.fabric8</groupId>
  <artifactId>docker-maven-plugin</artifactId>
  <extensions>true</extensions>
  <configuration>
    <images>  …  </images>
  </configuration>
  <executions>  …  </executions>
</plugin>
```

– Use multi-stage build to checkout sources and build in one container, then create new production container with build result only
Docker first

Container

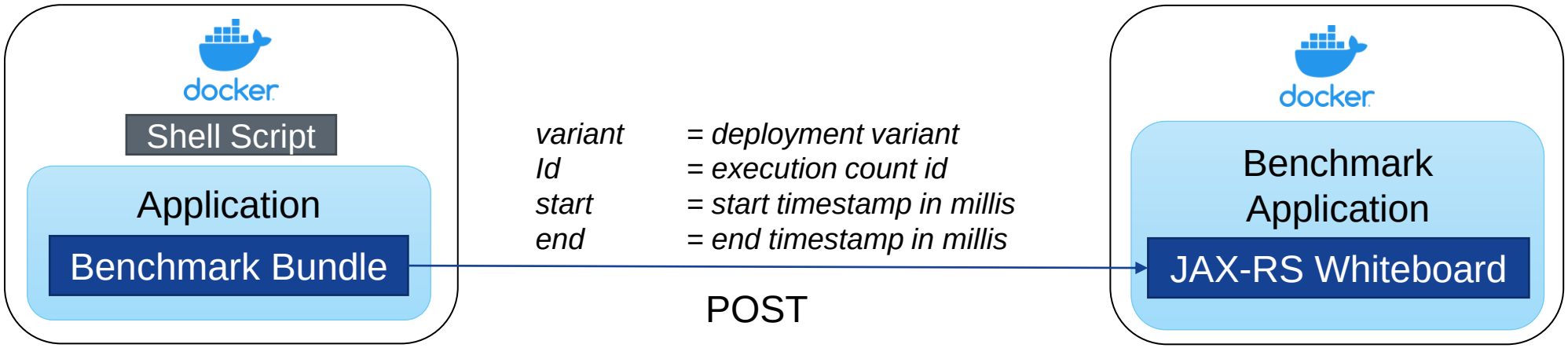
Deployment Variant – Base Image – Image Size

Deployment (plain OSGi)	Base Image	Size
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 171 MB
Executable JAR	eclipse-temurin:17-jre-alpine	~ 174 MB
Custom JRE (jlink)	alpine:3	~ 75 MB
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB

Deployment (OSGi Connect)	Base Image	Size
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 171 MB
Custom JRE (jlink)	alpine:3	~ 75 MB
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB
GraalVM Native Image	scratch alpine:3	~ 38 MB ~ 43 MB

Benchmark

Benchmark



Benchmark Bundle / Immediate Component

- Get start timestamp from system property
- Get current timestamp
- Send POST request via `java.net.http.HttpClient`
- Shutdown

Shell script

- Execute application multiple times in for-loop (clean/cache)
- Pass start timestamp as system property

Benchmark Images

Deployment Variant – Base Image – Image Size – Benchmark Image Size

Deployment (plain OSGi)	Base Image	Size	Size Benchmark
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 171 MB	~ 173 MB
Executable JAR	eclipse-temurin:17-jre-alpine	~ 174 MB	~ 176 MB
Custom JRE (jlink)	alpine:3	~ 75 MB	~ 78 MB
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB	~ 55 MB

Deployment (OSGi Connect)	Base Image	Size	Size Benchmark
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 171 MB	~ 173 MB
Custom JRE (jlink)	alpine:3	~ 75 MB	~ 78 MB
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB	~ 55 MB
GraalVM Native Image	scratch alpine:3	~ 38 MB (~ 43 MB)	(~ 46 MB) ~ 53 MB

+ `coreutils` nanosecond support
+ `benchmark` bundle
+ `java.net.http` module
+ shell script support

Benchmark Results

Deployment (plain OSGi)	Base Image	Size	Size Benchmark	Startup Clean	Startup Cache
Multiple JARs in folder	eclipse-temurin:17-jre-alpine	~ 171 MB	~ 173 MB	~ 982 ms	~ 901 ms
Executable JAR	eclipse-temurin:17-jre-alpine	~ 174 MB	~ 176 MB	~ 1087 ms	~ 1099 ms
Custom JRE (jlink)	alpine:3	~ 75 MB	~ 78 MB	~ 1336 ms	~ 1345 ms
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB	~ 55 MB	~ 1497 ms	~ 1505 ms

Deployment (OSGi Connect)	Base Image	Size	Size Benchmark	Startup Clean	Startup Cache
Multiple JARs in folder classpath modulepath	eclipse-temurin:17-jre-alpine	~ 171 MB	~ 173 MB	 ~ 1122 ms ~ 1194 ms	 ~ 973 ms ~ 1052 ms
Custom JRE (jlink)	alpine:3	~ 75 MB	~ 78 MB	~ 1439 ms	~ 1326 ms
Custom JRE (jlink/compressed)	alpine:3	~ 53 MB	~ 55 MB	~ 1593 ms	~ 1445 ms
GraalVM Native Image	scratch alpine:3	~ 38 MB (~ 43 MB)	(~ 46 MB) ~ 53 MB	- ~ 34 ms	- -

Conclusion

Conclusion

- All Java deployment variants possible for OSGi applications via
  - Bndtools JPMS support
  - OSGi Connect (Felix Atomos)

- Different deployment variants have different startup & runtime behaviors
  Consider JIT vs. AOT compilation

- Make decision about variant dependent on the use case,
  e.g. short running executables in container vs. long running application servers

- Further optimizations possible by configuring the Java runtime,
  e.g. Container-awareness, Garbage Collection, *Checkpoint & Restore*, etc.

Checkpoint/Restore in Userspace (CRIU)

"AOT like startup performance with JIT runtime performance and behaviour"

- **CRaC (Coordinated Restore at Checkpoint)**
  - OpenJDK CRaC JDK
  - Azul Zulu JDK with CRaC support
  - Enable via `-XX:CRaCCheckpointTo=<path>`
  - Create a checkpoint via `jdk.crac.Core` API
  - Create a checkpoint via `jcmd <PID> JDK.checkpoint` from separate shell process

- **Open Liberty InstantOn / OpenJ9 CRIU support**
  - IBM Semeru (OpenJDK/OpenJ9)
  - Enable via `-XX:+EnableCRIUSupport`
  - Creating a checkpoint via `org.eclipse.openj9.criu.CRIUSupport` API

Checkpoint/Restore in Userspace (CRIU)

Current issues

- **CRaC (Coordinated Restore at Checkpoint)**
  - Only Linux, currently no Alpine (musl) variant available
  - Building a custom JRE (jlink) currently not easily possible (need to manually copy criu to the system)
  - Containers with CRaC support not yet available out-of-the-box

- **Open Liberty InstantOn / OpenJ9 CRIU support**
  - Only Linux, no Alpine
  - Building a custom JRE (jlink)?
  - Creating a checkpoint only possible via API

News

– April 2023
  Azul Zulu builds with CRaC support generally available for Java 17 on Linux

– June 2023
  Open Liberty InstantOn out of beta with release 23.0.0.6

– June 2023
  Oracle announced **Oracle GraalVM** distributed under **GraalVM Free License** with release 23.0
  → Oracle GraalVM Enterprise now available for free
  → Container images not yet available

Benchmark Sources

https://github.com/fipro78/osgi_deployment_options

Thank you

Dirk Fauth
ETAS/ENA
dirk.fauth@etas.com